NOTE ON HIGH FREE-AIR WIND VELOCITIES OBSERVED DECEMBER 16 AND 17, 1919.

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On the morning of December 17, 1919, a remarkably high wind was observed in the free air above Lansing, Mich. This observation was made by the single theodolite method, altitudes being computed from the pilot balloon's rate of ascent by means of the formula $V = 71\left(\frac{l^3}{L^2}\right)^{.208}$, in which—

V = velocity,
l = balloon's free lift,
and L = balloon's total lift.[1]

The balloon was kept in sight 31 minutes, at the end of which time its computed altitude was 7,440 meters, its horizontal distance from the station, 87 kilometers, and its speed, 74 m. p. s., or 166 miles per hour. At the end of the preceding minute the computed wind velocity at an altitude of 7,200 meters was 83 m. p. s., or 186 miles per hour. So far as known, this is the highest wind speed ever observed at altitudes lower than 10 kilometers.[2]

[1] For development and discussion of this formula see Sherry, B. J., and Waterman, A. T. The Military Meteorological Service in the United States During the War. MONTHLY WEATHER REVIEW, April, 1919, p. 218.

[2] Clayton and Fergusson observed cirrus moving at 103 m. p. s. (230 m. p. h.) at an altitude of 11¼ kilometers. Annals of the Astronomical Observatory of Harvard College. Vol. XXX, pt. 3, p. 256. A velocity of 83 m. p. s. (186 m. p. h.) *was recorded* on Mount Washington in 1878. MONTHLY WEATHER REVIEW, January, 1878, p. 10 and American Weather, by A. W. Greely, p. 177.

The wind was unusually steady in direction, its variation from northwesterly between 2,500 and 6,500 meters altitude being at no time greater than 5°. Above 6,500 meters it backed to WNW. and below 2,500 meters it was nearly NNW.

There is always some hesitation in accepting as reliable a record of this kind, when obtained with only one theodolite, because a leaky or otherwise defective balloon would gradually assume a lower ascensional rate than that with which it started, with the result that much higher velocities would be indicated than actually existed. In this case, however, there is reason to believe that the record is substantially correct, for the following reasons: First, the afternoon run at the same station showed a similar, though somewhat less rapid, increase in wind velocity with altitude; second, records on the same day and on the previous day at other stations in the northern part of the country give similarly high values in the lower 3 kilometers. Unfortunately, none of these soundings reached as great an altitude as did the one at Lansing. In Table 1 are given the wind directions and velocities as observed at these stations, only those being included in which the balloon was followed to a height of at least 2 kilometers.

TABLE 1.—*Free-air winds observed in the northern part of the United States on Dec. 16 and 17, 1919.*

Stations.	December—	Time (local standard).	Altitude (meters) above surface. Surface.		250		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		6,000		7,000	
			Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).
Lansing, Mich.	17	7:20 a. m.	nnw.	2	n.	7	nnw.	8	nnw.	12	nw.	15	nw.	21	nw.	29	nw.	36	nw.	58	nw.	64	nw.	81	wnw.	80
	17	3:12 p. m.	s.	1	sse.	2	s.	1	nw.	3	nnw.	8	nnw.	11	nnw.	15	nw.	25	nw.	40						
Ellendale, N. Dak.	16[1]	10:29 a. m.	nne.	6	ne.	8	nne.	7	nnw.	7	nw.	12	nw.	17	nw.	20										
	16	2:30 p. m.	ene.	5	ene.	4	ne.	4	wnw.	10	wnw.	15	wnw.	21	wnw.	25	wnw.	30								
	17[1]	9:27 a. m.	se.	8	sse.	9	s.	11	wsw.	13	wnw.	17	nw.	20												
Fort Omaha, Nebr.	17	3:00 p. m.	se.	3	ssw.	4	w.	8	wnw.	14	nw.	15	nw.	21	nw.	24										
Drexel, Nebr.	16[1]	10:20 a. m.	wsw.	3	wsw.	6	w.	13	w.	13	wnw.	14	wnw.	17	wnw.	20	wnw.	23								
	16[1]	2:14 p. m.	nw.	2	nw.	9	nw.	12	wnw.	15	wnw.	17	wnw.	19	wnw.	20	wnw.	23								
	16[1]	5:47 p. m.	n.	2	nnw.	10	nw.	15	nw.	21	wnw.	23	wnw.	24	wnw.	27										
	16[1]	9:37 p. m.	nne.	4	nne.	8	n.	11	nnw.	14	nw.	15	wnw.	19	wnw.	24										
	17[1]	5:29 a. m.	se.	5	sse.	7	s.	10	sw.	16	w.	20	w.	23	w.	24										
	17[1]	10:07 a. m.	se.	5	s.	10	ssw.	13	w.	18	wnw.	21	wnw.	25	nw.	25										
	17[1]	2:01 p. m.	sse.	4	ssw.	7	w.	10	wnw.	14	nw.	18	nw.	22	nw.	26										
Madison, Wis.	16	3:00 p. m.	nnw.	2	nnw.	5	nnw.	7	wnw.	15	wnw.	25	wnw.	22												
	17	7:11 a. m.	nne.	7	nne.	9	nne.	11	nnw.	12	nw.	20	wnw.	26												
Royal Center, Ind.	16	2:01 p. m.	sw.	2	w.	2	w.	6	w.	16	wnw.	23	wnw.	36												
Camp Knox, Ky.	17	8:00 a. m.	n.	6	ene.	7	ne.	5	n.	11	nnw.	17	nnw.	22												
Burlington, Vt.	17	8:09 a. m.	n.	4	n.	8	nnw.	8	wnw.	7	w.	8	w.	16	w.	19	w.	18								
Aberdeen, Md.	16	8:05 a. m.	w.	4	wnw.	6	wnw.	9	wnw.	25	wnw.	25	wnw.	25	wnw.	39										
Washington, D. C.	16	8:16 a. m.	nnw.	2	nnw.	7	nw.	11	w.	17	wnw.	23	wnw.	27												
	16	3:09 p. m.	s.	2	ssw.	3	sw.	7	sw.	14	w.	15	wnw.	26												
	17	3:27 p. m.	nw.	7	nw.	6	nw.	6	nw.	11	nw.	20	wnw.	30	wnw.	35										
Fort Monroe, Va.	16	8:00 a. m.	wnw.	3	w.	12	w.	12	wnw.	9	nw.	18	nw.	25	wnw.	27	wnw.	19								
	17	7:55 a. m.	w.	6	w.	13	w.	18	wnw.	18	wnw.	22	wnw.	28												
Langley Field, Va.	16	8:22 a. m.	wnw.	7	nnw.	11	nnw.	11	nnw.	10	n.	20	nnw.	31	wnw.	33										
	16	2:30 p. m.	sw.	6	wsw.	6	wsw.	8	w.	14	wnw.	24	wnw.	20	wnw.	23										
Leesburg, Ga.	16	7:24 a. m.	n.	3	ne.	5	ene.	5	ne.	8	n.	10	n.	9	nnw.	11	nw.	13	wnw.	20	wnw.	31				
	16	3:08 p. m.	0	0	0	0	0	0	nnw.	3	nnw.	9	nw.	10	nw.	10	wnw.	12	wnw.	17	wnw.	26				
	17	7:24 a. m.	w.	2	wnw.	12	wnw.	14	wnw.	16	wnw.	14	w.	12	w.	14	wnw.	17	wnw.	15	nw.	22				
	17	2:53 p. m.	wnw.	7	wnw.	7	wnw.	10	wnw.	10	wnw.	16	wnw.	18	nw.	14										

[1] From kite flights.

The figures in this table show that, except at and near the earth's surface, a northwesterly to west-northwesterly current prevailed throughout the northern part of the country east of the Rocky Mountains. At nearly all places the wind velocity rapidly increased with altitude, reaching at 7,200 meters above Lansing, as already stated, a value of 83 m. p. s.

An inspection of the weather maps for these two days shows that there was but little surface barometric activity: High pressure was central over the southern States on both days; another high pressure area, central north of Minnesota on the 16th, moved southeastward to the Lake region by the evening of the 17th; pressure was relatively low between these highs and, in addition, a poorly developed LOW moved from the Upper Lake region eastward and then northeastward to the vicinity of Newfoundland. Figure 1 shows the pressure

FIG. 1.—Sea-level isobars and surface-wind directions at 8 a. m., 75th meridian time December 17, 1919.

distribution prevailing at 8 a. m., 75th meridian time, December 17, 1919; also, the resulting surface wind directions. These winds ranged in speed from about 2 m. p. s. in the southern States to about 8 or 10 m. p. s. in the northern and middle western States. As indicated in Table 1, the influence of the surface pressure distribution appears not to have extended to a height greater than 1,000 meters above the surface, or less than 1,500 meters above sea level. At all higher levels the trend of the isobars, if parallel or nearly parallel to the winds, was from west-northwest to east-southeast. Further inspection of the weather maps shows that there was a strong south-to-north temperature gradient, unusually cold weather prevailing north of the Lake region, and that the isotherms likewise extended from west-northwest to east-southeast, or parallel in general to the free-air isobars and wind directions. This is well shown in figure 2, in which the solid lines represent surface temperature conditions at 8 a. m., December 17, 1919. The effect of this horizontal temperature gradient was a constantly increasing horizontal pressure gradient as greater altitudes were reached. That this condition actually existed is shown in the kite observations at Ellendale, N. Dak., and Leesburg, Ga. Near the surface there was practically no difference, but at 2,500 meters above sea level the pressure was 18 millibars higher at Leesburg than at Ellendale. The line joining these stations is not at right angles to this pressure gradient, but if we extend the 2,500-meter isobars in a direction parallel to that of the winds at that level, as indicated by the broken lines, figure 2, we find that the distance between those isobars was approximately 900 kilometers, and, if we can still further assume that these are straight isobars, we obtain a gradient wind velocity of about 23 m. p. s., a value differing but little from those given in Table 1 for the 2,500-meter level. At greater altitudes much higher velocities would be expected, not only because of the increasing pressure gradient, but also because of the diminishing air density. Kite records at Ellendale, Drexel, and Leesburg show that at the 2,500-meter level there still persisted a fairly strong temperature gradient from south to north, and it is probable that this increased as higher latitudes were reached, north of the Lake region, for example. The result would be an increasing pressure gradient with altitude, but even if this gradient had remained constant, i. e., the same as at 2,500 meters, the wind would nevertheless have increased, since in the equation for gradient winds the density term occurs in the denominator.

This case and numerous other similar cases bring out clearly the relation between the surface horizontal temperature distribution, in its effect on free-air pressure gradients, and the winds in the middle and upper portions of the troposphere. Surface pressure systems have little influence in this respect, except in so far as they produce modifications in the surface temperature distribution. Naturally, these pressure systems exert a greater or less influence, in proportion as they are well or poorly developed, and during the summer, when latitudinal temperature gradients are weak, they occasionally control the free-air winds to great heights. Thus, easterly winds to a height of 10 kilometers were observed in the southern States during the approach of the West Indian hurricane of September, 1919. During this period "pressure was relatively high over the southern Appalachian region and the interior of the east Gulf States,"[3] and there was little change in temperature from north to south. It has been shown also that in the middle western States cirrus movement from the east is practically never observed except in the summer half of the

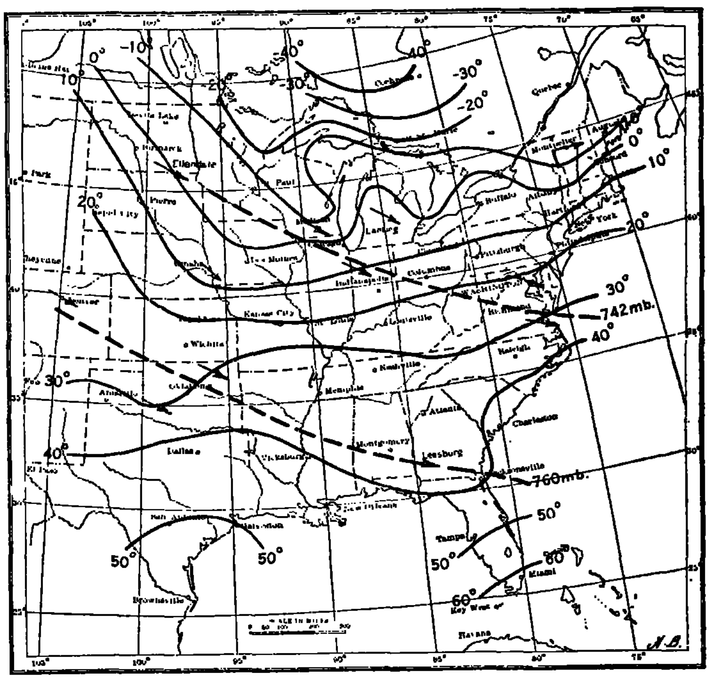

FIG. 2.—Surface isotherms (solid lines), 2,500-meter isobars or instantaneous stream lines (broken lines), and 2,500-meter wind directions (arrows) at 8 a. m., meridian time December 17, 1919.

year when temperature gradients are weak and when moderately high pressure is central northeast of the regions where such movement is noted.[4] Except under abnormal conditions of temperature distribution easterly winds in the higher portions of the troposphere can not occur during the winter half of the year.

[3] For full discussion see "The West India hurricane of September, 1919, in the light of sounding observations." By R. H. Weightman. MONTHLY WEATHER REVIEW, October, 1919, pp. 717–720.

[4] MONTHLY WEATHER REVIEW, October, 1919: The relationship between cirrus movements from easterly points and the occurrence of severe droughts (by George Reeder, pp. 711-715); *Easterly movement of cirrus clouds* (by L. J. Guthrie, pp. 716-717).